NOTES AND LITERATURE

BIOMETRIC STUDIES ON THE SOMATIC AND GENETIC PHYSIOLOGY OF THE SUGAR BEET

THE beet sugar industry, amounting to hundreds of millions of dollars every year, is the direct result of scientific breeding.

A biologist is loath to demur at any statement which attaches economic importance to scientific work of the kind in which he is interested. The statement may be true. Certainly no one can deny that far greater system and standardization of routine has obtained in the beet sugar industry than in many other branches of agriculture. But the trained scientific man who conscientiously works through some thousands of pages of the literature of sugar beet breeding and cultivation must hesitate before regarding it as a triumph of scientific method. He will rather, I think, feel that science has fallen woefully short of its possibilities in dealing with many problems of great theoretical interest and economic significance.

In no field of agricultural work is the failure of scientific and practical men to cooperate less excusable than in that of sugar-beet breeding. In the routine operations of sugar-beet production chemical data of a relatively satisfactory degree of trustworthiness are obtained for great numbers of individuals. It is not unconservative to say that millions of individual weighings, polarizations or analyses of various degrees of completeness have been made. For two decades the biometric formulæ which might have given meaning to some of these masses of data have been available. Yet the problems which might have been solved have remained unelucidated, to the material loss of both biology and industry.

It seems worth while to illustrate the truth of these statements by some of the advances in our knowledge of the genetic and somatic physiology of the sugar beet which have been made possible by the application of the biometric formulæ.

Consider first of all one of the simplest problems—that of the relationship between the weight of the root and the sugar content of its juice. Notwithstanding considerable discussion this

very simple problem was not definitely solved until 1913 when actual correlations[1] were available. Coefficients ranging from —.224 to —.756 for the relationship between weight of root and sugar content of juice in various short series of data were found. The results were published only after failure in a conscientious and systematic effort to obtain from the agricultural experiment stations really adequate series of data for detailed biometric analysis.

Fortunately the conclusions have since been fully confirmed. Pritchard,[2] in dealing with samples of 250 to 400 beets grown at Fairfield, Washington, found constants ranging from —.253 to —.499. Working with larger samples ($n = 3.784$) from Brookings, S. D., he found $r = -.258$, while Harris and Hogensen,[3] who had a sample of nearly 7,000 beets[4] from Utah cultures, found $r = -.288$.

The splendid work of these investigators leaves no doubt that the percentage sugar content decreases, and, as Harris and Gortner indicated on their limited series of data, in a sensibly linear manner, with increase in weight of root.

These studies, based as they are in some of these series, at least, upon closely bred material, fully justify the criticisms of the conclusions of Andrlik, Bartoš and Urban[5] by Harris and Gortner.[6]

Harris and Gortner have also found negative correlations between weight of root and total solids and coefficient of purity. Thus the larger roots have a smaller quantity of total solids, a lower percentage sugar content and a lower coefficient of purity.

[1] Harris, J. Arthur, and R. A. Gortner, "On the Relationship between the Weight of the Sugar Beet and the Composition of its Juice," *Jour. Ind. and Eng. Chem.*, 5, March, 1913.

[2] Pritchard, F. J., "Correlations between Morphological Characters and the Saccharine Content of Sugar Beets," *Amer. Jour. Bot.*, 3: 361–376, 1916.

[3] Harris, F. S., and J. C. Hogensen, "Some Correlations in Sugar Beets," *Genetics*, 1: 334–347, 1916.

[4] Unfortunately the constant is not altogether trustworthy because the largest and the smallest roots were excluded.

[5] Andrlik, K., V. Bartoš and J. Ürban, "Uber die Variabilität des Gewichtes und des Zuckergehaltes der Zuckerrübenwurzeln, und über die gegenseitigen Beziehungen dieser beiden Merkmale," *Zeitschr. f. Zuckerindustrie in Böhmen*, 36: 193, 1912.

[6] Harris, J. Arthur, and R. A. Gortner, "Further Notes on the Relationship between the Weight of the Sugar Beet and the Composition of its Juice," *Biochem. Bull.*, 2: 524–529, 1913.

That large roots yield an actually larger amount of sugar is to be expected, and Pritchard's coefficient for the correlations between weight of root and total sugar content is high.

Such results are obviously of great practical significance. Laying aside the possible desirability of modifying planting or cultivation in such a manner as to influence root size, the question of the selection of roots for sampling is one of real importance.

Much of the early American work on the sugar beet was devoted to determining where the crop will give a yield per acre and a sugar content and coefficient of purity satisfactory for economic work. Roots were sent by farmers to the Agricultural Experiment Stations, analyzed, and the results published in a great series of bulletins. But since size and percentage of sugar are correlated, and selection for size in the submitting of samples was rarely guarded against, the great mass of figures have little significance as measures of the merit of the cultures from which the samples were drawn.

If physical characters of the root be associated with sugar content or with purity of the juice, which is technically a highly important factor, physical characters may serve as a guide to selection.

Pritchard has devoted great care to the problem of the correlation between a number of the morphological features of the root and leaf and sugar content, and has determined the average percentage of sugar and average sugar content in synthetic types, *i. e.*, those embodying the most desirable of the morphological characteristics. The results are of technical rather than of general biological interest. The conceptions of a synthetic type—a conception that has already been emphasized in a quite different way by Raymond Pearl[7]—is well worth careful consideration by all those who have to do with breeding problems.

Both Pritchard[8] and Harris and Hogensen have extended their studies of the correlation of characters in the root to that of the interrelationship of the characters of the root and those of the fruiting shoots.

[7] Pearl, R., and F. M. Surface, "Selection Index Numbers and their Use in Breeding," AMER. NAT., 43: 385–400, 1909. Also, R. Pearl, "Further Notes Regarding Selection Index Numbers," AMER. NAT., 46: 302–307, 1912.

[8] Pritchard, F. J., "Some Recent Investigations in Sugar Beet Breeding," *Bot. Gaz.*, 62: 425–465, 1916.

They agree that there is no correlation between the sugar content of a beet and the quantity of seed which is produced, but Harris and Hogensen find a correlation of $.308 \pm .013$ for the relationship between the weight of the seed beet planted and the weight of seed produced, whereas Pritchard, from a number of determinations, concludes that for beets of ordinary size such as are grown for factory use the correlation between root weight, percentage of sugar in roots and quantity of sugar in the seed root on the one hand and the number of grams of seed produced by the seed root is sensibly zero.

Harris and Hogensen find a correlation of about $+.399$ between height of plant and amount of seed produced, about $+.277$ between number of stems and weight of seed produced, and about $+.122$ between number of leaves and weight of seed produced.

Pritchard has shown that there is no correlation between the amount of seed which a beet root yields and the sugar content of its progeny. "The application of this fact to sugar breeding," says Pritchard, "is obvious, as extensive selection may be made for freer seed production without danger of sugar deterioration. Moreover, it affords an opportunity to reverse the order of selection by making the chief elimination in the seed generation and thus greatly reduce the amount of chemical work and increase the effectiveness of the working funds."

The physiological character *time required for maturing seed* has received some attention by Harris and Hogensen, who find a greater height and a higher production of seed in beets requiring a longer period for maturity. The coefficients are, however, low, $r = +.175 \pm .016$ for height and days required for maturing seed and $r = +.195 \pm .016$ for days required for maturity and quantity of seed produced. The correlation between the percentage of sugar in the mother beet and the number of days required for maturing seed is negative, $r = -.129 \pm .014$, *i. e.*, the beets with higher sugar content mature their seed more rapidly.

All these coefficients are very low. The experienced statistician will be cautious in regarding them as significant, remembering that when constants reach minimum values probable errors can not be given their normal weight. Those who have had personal experience in the biological phases of such work will realize its difficulties, and allow the questions of the significance of these correlations to remain open until more extensive

data are available. There are, furthermore, internal evidences of serious heterogeneity in the materials upon which these constants are based. Such irregularities as those seen in the frequency distributions of number of days required for maturing require explanation before coefficients based upon them can be given much weight.

The result of Pritchard's experiments which will arouse the widest interest is the conclusion that with due regard to the probable errors of random sampling, there is no correlation between the weight of the mother roots and the average weight, the average percentage sugar content or the average total sugar content of the progeny roots, that there is no correlation between the percentage of sugar in the mother beets and the average percentage of sugar in their progeny, between the actual amount of sugar in the mother beets and the actual amount of sugar in the progeny roots.

Thus in dealing with our long selected varieties of sugar beets the author is faced to the conclusion:

> Differences in the size and sugar content of individual beet roots show no evidence of inheritance. They are fluctuations, therefore, and apparently play no part in beet improvement.

The practical consequences of such a conclusion should be self evident. One European firm is said to carry out 300,000 analyses annually in the selection of roots for seed production. If the conclusion reached by Pritchard be of final significance, it justifies the assertion that "the cost of analyzing mother beets is an absolute waste of money."

Space precludes a discussion of the data given by Pritchard on the average composition of progeny rows and on the influence of environmental factors in observing genetic differences. From this side his paper must be read, and will later be reviewed in connection with one on the technical features of progeny tests.[9]

His studies show how small are the real genetic differences which may appear, how deeply these differences may be buried under those due to environmental factors, and how difficult in consequence must be the attainment of real progress in the further improvement of so highly selected an agricultural plant as the sugar beet.

[9] Pritchard, F. T., "The Use of Checks and Repeated Plantings in Variety Tests," *Jour. Amer. Soc. Agron.*, 8: 65–81, 1916.

Pritchard is a mutationist rather than a selectionist.

The selection of choice roots by chemical and physical means has probably played no part in sugar beet improvement except where an occasional root has mutated and thus given rise to a superior physiological species.

One does not need to agree with the form of Pritchard's conclusion to recognize the great value of such studies as those which he has carried out. Full knowledge of the difficulties surrounding a task is one of the essentials to its accomplishment. When all the variables that enter into the problem of sugar-beet production and sugar-beet breeding are known in quantitative terms, it will be possible for the practical man to decide on the basis of the cost of labor and other economic considerations what operations can be dispensed with and what other changes in routine can be profitably made. Operations can then be more properly designated *scientific*.

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